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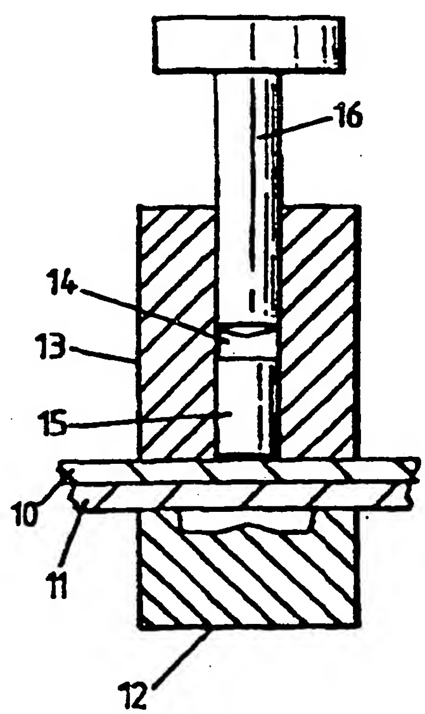
(54) Title: SELF-PIERCING RIVETING

(57) Abstract

A method of self-piercing riveting comprising inserting a self-piercing rivet (15) into a workpiece consisting of at least two layers (10, 11) of overlapping material such that the end of the rivet is deformed during the riveting process and remains encased in the material furthest from the point of impact of the rivet (15), characterised in that during at least part of the riveting process the sides of the rivet (15) are constrained against radially outward deformation in the region where the rivet enters the workpiece.



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# SELF PIERCING RIVETING

## Field of the Invention

The present invention relates to self-piercing riveting. It is particularly, but not exclusively, applicable to a method and apparatus for joining workpieces using rivets which have a reduced strength difference between the rivet and the materials being joined, and is specifically applicable to the use of rivets of the same composition as the workpieces.

## Background to the Invention

Self-piercing is a method of riveting in which no aperture is performed in any of the workpieces to be riveted together, the rivet itself penetrating at least the nearest workpiece component. Usually it is arranged that the rivet does not penetrate the most remote workpiece, so that the resulting riveted joint is inherently sealed against the passage of gas or liquids.

Self-piercing riveting has been developed as an alternative to spot welding and as such offers certain advantages. A number of such self-piercing riveting systems are commercially available for example under the Trade Marks FASTRIV and HENROB. Such systems are described in the patent literature, for example in WO93/10925 (HENROB), WO94/14554 (HENROB) and US4,615,475 (NEITEK). This is the closest prior art known to the Applicant and the reader is referred to these documents for a general description of this method and its advantages over spot welding.

These prior art systems share certain common features. First, they utilise a rivet which has a performed head, and this head has to be accommodated within the die of the placing apparatus.

Secondly, existing methods do not give consistently reliable results unless the rivets are substantially stronger than the component to be joined. Importantly, since this method is often used with relatively hard aluminium alloy workpieces, there is a requirement to use rivets which are also of aluminium alloy. This would avoid any tendency towards chemical or galvanic corrosion or the like and would simplify the recovery of the aluminium alloy material for recycling. However, this requirement cannot currently be satisfied, since there is no sufficiently stronger aluminium alloy available for the rivet.

It is the object of the present invention to overcome or mitigate one or more of the disadvantages outlined above.

## Summary of the Invention

According to the first aspect of the present invention, in its broadest sense, there is provided a method of self-piercing riveting comprising inserting a self-piercing rivet into a workpiece consisting of at least two layers of overlapping material such that the end of the rivet is deformed during the riveting process and remains encased in the material furthest from the point of impact of the rivet, characterised in that during at least part of the riveting process the sides of the rivet are constrained against radially outward deformation in the region where the rivet enters the workpiece.

By supporting the external shank of the rivet as it enters the workpiece the rivet material no longer has to be substantially stronger than the workplace. For the first time a reliable method is available for using aluminium alloy rivets for joining relatively hard aluminium alloy workpieces.

Preferably the constraint against radially outward deformation extends away from the workpiece for substantially the complete length of the rivet.

By selecting a headless rivet the entire shank of the rivet can be supported, thus avoiding any tendency for the rivet to deform outwardly before it enters the workpiece.

Preferably the constraint is removed after the rivet has at least partially entered the workpiece, thereby allowing radially outward deformation of a portion of the rivet to form a rivet head.

In this manner a head is formed automatically as the rivet is driven home.

Preferably the aforesaid rivet head is so formed that it does not substantially project above the surface of the workpiece.

In a further embodiment the constraint against radially outward deformation is maintained in place until the rivet is entirely within the workpiece, such that the deformation of the rivet which inevitably takes place in such a riveting process results in radially outward deformation of a portion of the rivet to form a head within the layer of material first penetrated by the rivet.

Because it is now possible to constrain the rivet from deforming until it has entered the workpiece, it is possible to form an enlarged head within the workpiece rather than in a countersunk region on its outer surface.

In a particularly preferred embodiment, the rivet comprises a cylindrical slug of material, the sides of the cylinder being parallel along substantially the entire length of the rivet.

The rivets can thus be formed simply by cropping pieces off the end of a length of wire, resulting in significant cost savings.

In an alternative embodiment, the rivet comprises a semi-tubular slug incorporating a bore with a tapered outer end at the end of the rivet intended to penetrate the workpiece.

Preferably, the rivet comprises a semi-tubular slug incorporating at both ends a bore with a tapered outer end, thus obviating the need to orientate the rivet with respect to the workpiece prior to deformation.

A tapered end provides a piercing region to ease penetration of the workpiece. By making the rivet symmetrical this eliminates the need to orientate the rivet during presentation to the riveting head.

Preferably, the method comprises the additional step of forming rivets immediately prior to use by repeatedly cropping the tip off a length of wire.

By forming the rivets as required, as part of a single riveting operating, considerable savings can be made in cost, time and operational simplicity.

Preferably, the constraint provides both a force resisting radially outward deformation of the rivet but also exerts a force to clamp the workpiece in place.

Where an anvil and die arrangement are used, this can also clamp the components of the workpiece together.

In a further aspect of the present invention, in its broadest sense, there is further provided an apparatus for performing the above self-piercing method comprising:

(i) an anvil;

(ii) a die incorporating a channel adapted to convey a rivet to the workpiece, the anvil and die in combination being adapted in use to firmly clamp the workpiece;

(iii) a punch adapted to drive the rivet into the workpiece;

(iv) constraining means adapted in use to prevent radially outward deformation of the rivet as the rivet enters the workpiece.

In a particularly preferred embodiment the sides of the channel in the die provide the desired constraint against radially outward deformation.

Thus by adapting the die to provide the necessary support for the rivet as it enters the workpiece existing apparatus can be modified to perform the new method.

In a further embodiment the constraining means comprises moveable heads adapted to encircle the shank of the rivet as it enters the workpiece, the heads being interposed between the die and the workpiece and being moveable away from the shank.

Where it is required to use headed rivets this prevents the use of a straight-sided die. However, since constraint is required primarily where the rivet enters the workpiece this can be provided by one or more heads which move up to and away from the rivet as required.

__Brief Description of the Drawings__

Aspects of the present invention will now be more particularly described by way of example only and with reference to the accompanying drawings in which:-

Figures 1 to 5 are sectional side views illustrating diagrammatically the sequential steps in a method of self-piercing riveting according to a first embodiment of the invention;

Figures 6 to 9 are sectional side views of the sequential steps in a method of self-piercing riveting according to a second embodiment of the invention;

Figures 10 and 11 are sectional side views showing the additional step of forming a rivet by wire cropping and introducing the rivet thus formed into a die;

Figures 12 and 13 are sectional views illustrating the initial sequential steps of a method of self-piercing riveting using a headed rivet;

Figures 14 to 16 illustrate side cross-sections through three types of self-piercing rivets applicable to the present invention;

Figures 17 to 20 are sectional side views of the sequential steps in a method of self-piercing riveting according to a fourth embodiment of the invention.

## Description of the Preferred Embodiment

The present embodiments represent currently the best ways known to the Applicant of putting the invention into practice. But they are not the only ways in which this could be achieved. They are illustrated, and they will now be described by way of example only.

Figures 1 to 5 illustrate the sequential steps in carrying out a first embodiment of a self-piercing riveting method. The panels or components 10,11 to be joined together are supported between an anvil 12 and a die 13. The die incorporates a straight-sided channel 14 which is a tight sliding fit for a rivet 15 and a punch 16.

The die and anvil clamp the two panels together to form a workpiece. The clamping force can be due to upward pressure from the anvil or, as shown in Figure 2, downward pressure P by the die 13.

In this context a workpiece consists of any number of components which are intended to be riveted together.

The anvil incorporates an annular cavity which allows a fixed amount of deformation of the workpiece and also causes the rivet to splay outwards as will be described below.

Referring now in detail to the sequence shown in Figures 1 to 5, in Figure 2 a downward compressive force P is applied to the sheets by the die. Force F is then applied to the punch causing the rivet to pierce into the sheets and the end of the rivet

to splay outwards by reacting against the anvil. At this stage there is sufficient volume of rivet left projecting above the top sheet to form the eventual rivet head.

In Figure 3, the die is withdrawn until the bottom of the die is level with the end of the punch. This leaves the remaining sides of the rivet projecting above the workpiece unsupported and unconstrained. The punch and die then move downwards in unison as shown in Figure 4 and upset the projecting end of the rivet to form a head. The head can be flush with the workpiece as shown or protruding depending on the design requirements.

Certain aspects and advantages of the invention will immediately become apparent. Firstly, the rivets consist of straight-sided slugs of material. There is no need to pre-form a rivet head. In their simplest form the rivets can be formed by simply repeatedly cropping the end of a length of wire (see reference below to Figures 10 and 11). Secondly, the internal dimensions of the channel 14 in the die correspond substantially exactly to the external dimensions of the rivet. Since the die is manufactured from material of great strength it provides a constraint against the inevitable tendency to radially outward deformation of the rivet when force F is applied. It thus acts to strengthen the rivet and the resulting effect is as if a rivet of much stronger material were being used. It is thus possible to join components together using rivets made of the same basic material (e.g. aluminium alloy) as the component parts, but having a reduced strength differential over the component material.

This method works well providing the die is kept in contact with the workpiece at least during the part of the riveting processing when the rivet starts to enter and penetrate the workpiece. Once both workpieces have been penetrated then the constraint can be removed in order for a head to be formed. The simplest

way to remove this constraint is to lift at least a portion of the die away from the workpiece. It will be appreciated that the die could be in two-part form with an outer, clamping component, which always remains in contact with the workpiece (not shown) and an inner component which moves as illustrated in these figures.

By using the arrangement described in the foregoing example, a workpiece or component material of aluminium alloy grade 5251 in the H3 condition having a hardness of Hv 85 can be satisfactorily riveted with a self piercing rivet manufactured from aluminium alloy grade 7050 having a hardness of Hv 150.

A further embodiment of this process is illustrated in Figures 6 to 9 inclusive. Figures 6 and 7 correspond to the steps shown in Figures 1 and 2. However, in Figure 8 the die is not withdrawn from the workpiece but instead continued pressure is applied by the punch 16. Continued forward movement of the punch causes expansion of the rivet sufficient for it to be securely engaged within the top panel. Where the rivet has comparable strength relative to the workpiece it has been discovered that the inevitable deformation takes place within the workpiece to form an embedded head rather than a countersunk head.

On many applications a sufficiently secure joint can be produced without the need for the rivet to have a fully formed head. This is particularly applicable where adhesives are the principal joining method and where a mechanical fixing is required to secure the component parts together until the adhesive is set.

Where a plain cylindrical rivet is used, the rivet can be produced at the riveting head by feeding wire into the head and cutting off the rivet by a cropping action and transferring the rivet into the die. This is illustrated in Figures 10 and 11.

A cutting block 20 is provided adjacent the rivet die 23 which contains an aperture 21 aligned with a corresponding aperture 27 in the die, enabling the rivet 25

to be fed directly into channel 24 as it is formed. Wire 22 is fed through the cutting block until it reaches a wire stop 28. The position of the wire stop in the cutting block is adjustable such that the length of the rivet can be adjusted to suit a variety of workpieces. This cropping technique is known per se but the sequential formation of rivets for feeding directly into an adjacent die has not previously been applied to this method. Whereas rivets in this type of apparatus and method are generally magazine or belt fed this embodiment avoids all the complexity of these earlier arrangements.

A third embodiment of the present invention is illustrated in Figures 12 and 13. There are occasions when it is preferable to use a rivet with a pre-formed head. It has been discovered that it is possible to use such rivets in these methods providing the shank of the rivet is constrained as it enters the workpiece. This can be achieved using the method illustrated in Figures 12 and 13. Moveable heads 30, 31 are interposed between the die 33 and the workpiece. The heads are shaped so that they conform to the circumference of the rivet as a tight sliding fit. The rivet 35 is then driven into the workpiece until the head of the rivet encounters the moveable heads 30, 31. The heads are then withdrawn and force F' is applied to the punch 36 to drive the rivet head into the workpiece.

In this example the heads move laterally in the plane of the workpiece. However, this is only one option and the heads could equally well move in an angled manner. The important feature is that the end of the die is adjustable in terms of the width of the rivet to provide both the necessary constraint and passage for the head of the rivet. Force F' may or may not be equal to force F.

Figures 17 to 20 illustrate a further embodiment of the present invention. In this embodiment the shaft of the rivet contains a circumferential groove 48 near the trailing end of the rivet. The groove is preferably positioned such that it aligns with

the sheet of material nearest to the die at the end of the riveting process. As the rivet is forced into the workpieces then material 49 from workpiece 40 is extruded into groove 48, gripping the rivet tightly in place and thus forming a stronger joint between the two workpieces.

In Figures 17 to 20 the groove 48 is shown as a circumferential channel. However, this is only one possible arrangement. For example, the so-called groove could consist of one or more indentations around the circumference of the rivet, each indentation being capable of accepting extruded material 49. It follows that the term "groove" has a broad meaning in this context and includes a depression of any shape or configuration which can achieve the desired result of accommodating an extruded or exuded part of workpiece 40.

In this embodiment it will be noted that it is not necessary or desirable to withdraw the die away from workpiece 40 during the riveting process in a head-forming step. That is to say the step shown in Figure 3 is omitted. This encourages material from sheet 40 to flow into groove 48.

The examples so far described have utilised cylindrical slugs as rivets as shown in Figure 16. However the slug need not be circular cylindrical but could be any appropriate cross-section including square, rectangular or polygonal. Furthermore, the end of the rivet which pierces the workpiece can be semi-tubular in shape as shown in Figure 15. That is to say the end of the rivet can incorporate a bore with a tapered end to assist in the piercing of the workpiece and the ultimate deformation of the rivet on the anvil. Semi-tubular rivets provide easier penetration of sheets, improved splaying, and reduced distortion of the joint because there is less material displacement.

In a further improved modification both ends of the rivets can contain a bore as shown in Figure 14. Symmetrical semi-tubular rivets eliminate the need to orientate the rivet during presentation to the riveting head.

These methods and apparatus are equally applicable to the application of tubular slugs or rivets (not illustrated). In this case a further punch designed to be a tight sliding fit within the bore of the rivet will be required to support the rivet against internal collapse. The bore of the rivet may be threaded to receive a fastener or plug to support for example an electrical wiring loom or a plastic insert to form a flush cover over the joint.

These methods are applicable to a wide variety of materials and enable rivets to be constructed from materials otherwise considered too weak to be useful. Thus as well as metals, plastics materials and composites can be used as selected by the materials specialist.

The scope of this invention is intended to encompass the apparatus necessary to carry out these methods. The skilled addressee of this specification is directed to the prior art specifications for general details on self-piercing riveting techniques. It will be appreciated that changes and modifications may be made to the embodiments described and illustrated without departing from the scope or spirit of the present invention defined in the following claims.

## CLAIMS

1. A method of self-piercing riveting comprising inserting a self-piercing rivet into a workpiece consisting of at least two layers of overlapping material such that the end of the rivet is deformed during the riveting process and remains encased in the material furthest from the point of impact of the rivet, characterised in that during at least part of the riveting process the sides of the rivet are constrained against radially outward deformation in the region where the rivet enters the workpiece.

2. A method according to Claim 1 wherein the constraint against radially outward deformation extends away from the workpiece for substantially the complete length of the rivet.

3. A method as claimed in Claim 1 or Claim 2 in which the constraint is removed after the rivet has at least partially entered the workpiece, thereby allowing radially outward deformation of a portion of the rivet to form a rivet head.

4. A method as claimed in Claim 3 in which the aforesaid rivet head is so formed that it does not substantially project above the surface of the workpiece.

5. A method as claimed in Claim 1 or Claim 2 in which the constraint against radially outward deformation is maintained in place until the rivet is entirely within the workpiece, such that the deformation of the rivet which inevitably takes place in such a riveting process results in radially outward deformation of a portion of the rivet to form a head within the layer of material first penetrated by the rivet.

6. A method as claimed in any preceding Claim wherein the rivet comprises a cylindrical slug of material, the sides of the cylinder being parallel along substantially the entire length of the rivet.

7. A method according to any preceding claim wherein the rivet incorporates a circumferential groove in its outer surface.

8. A method according to any preceding Claim wherein the rivet comprises a semi-tubular slug incorporating a bore with a tapered outer end at the end of the rivet intended to penetrate the workpiece.

9. A method according to Claim 8 wherein the rivet comprises a semi-tubular slug incorporating at both ends a bore with a tapered outer end, thus obviating the need to orientate the rivet with respect to the workpiece prior to deformation.

10. A method according to Claim 6 wherein the method comprises the additional step of forming rivets immediately prior to use by repeatedly cropping the tip off a length of wire.

11. A method as claimed in any preceding Claim wherein the constraint provides both a force resisting radially outward deformation of the rivet but also exerts a force to clamp the workpiece in place.

12. A method of self-piercing riveting substantially as herein described with reference to and as illustrated in any combination of the accompanying drawings.

13. Apparatus for effecting the method according to any of Claims 1 to 12 inclusive comprising:

(i) an anvil;

(ii) a die incorporating a channel adapted to convey a rivet to the workpiece, the anvil and die in combination being adapted in use to firmly clamp the workpiece;

(iii) a punch adapted to drive the rivet into the workpiece;

(iv) constraining means adapted in use to prevent radially outward deformation of the rivet as the rivet enters the workpiece.

14. Apparatus as claimed in Claim 13 wherein the sides of the channel in the die provide the desired constraint against radially outward deformation.

15. Apparatus as claimed in Claim 13 wherein the constraining means comprises moveable heads adapted to encircle the shank of the rivet as it enters the workpiece, the heads being interposed between the die and the workpiece and being moveable away from the shank.

16. Apparatus for self-piercing riveting substantially as herein described with reference to and as illustrated in any combination of the accompanying drawings.

FIG.5

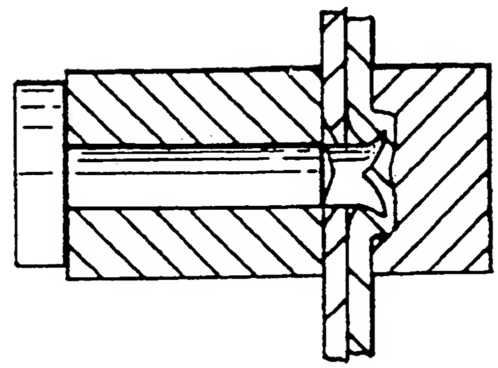

FIG.4

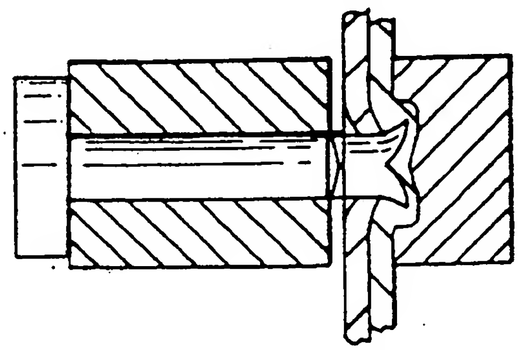

FIG.3

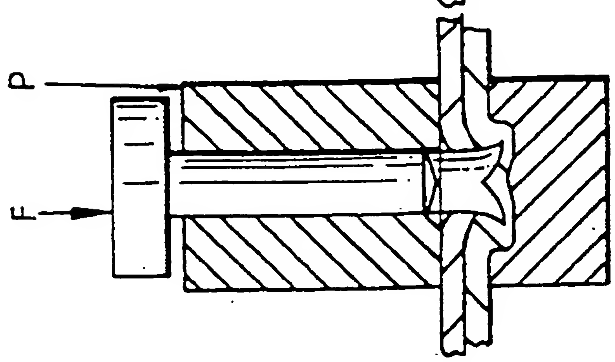


FIG.2

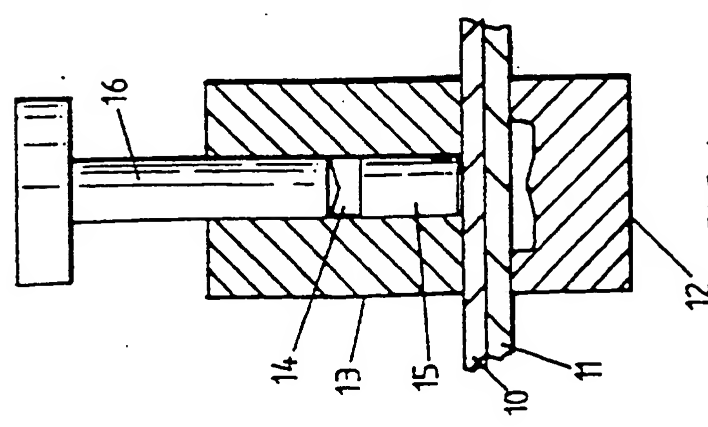


FIG.1

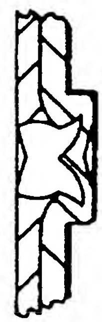

FIG.9

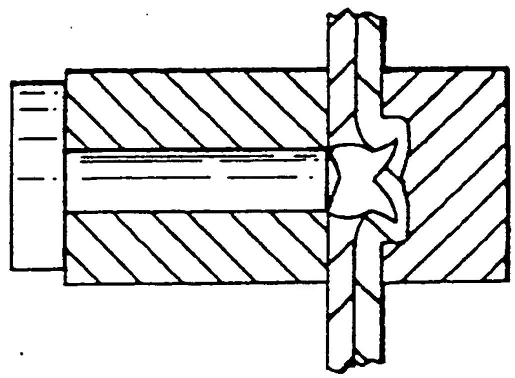

FIG.8

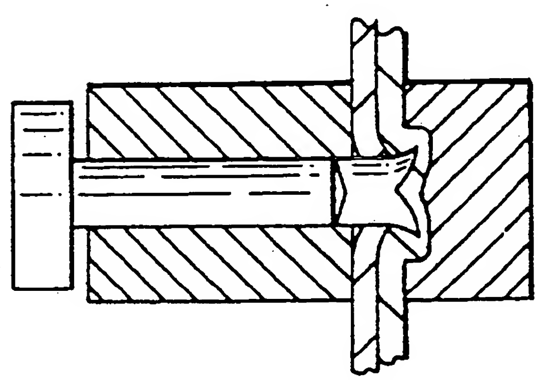

FIG.7

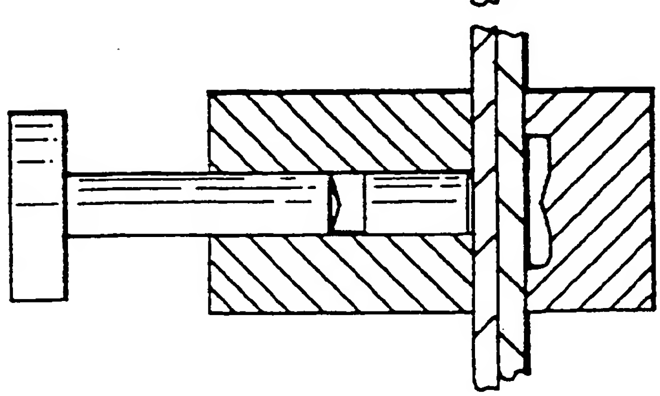

FIG.6

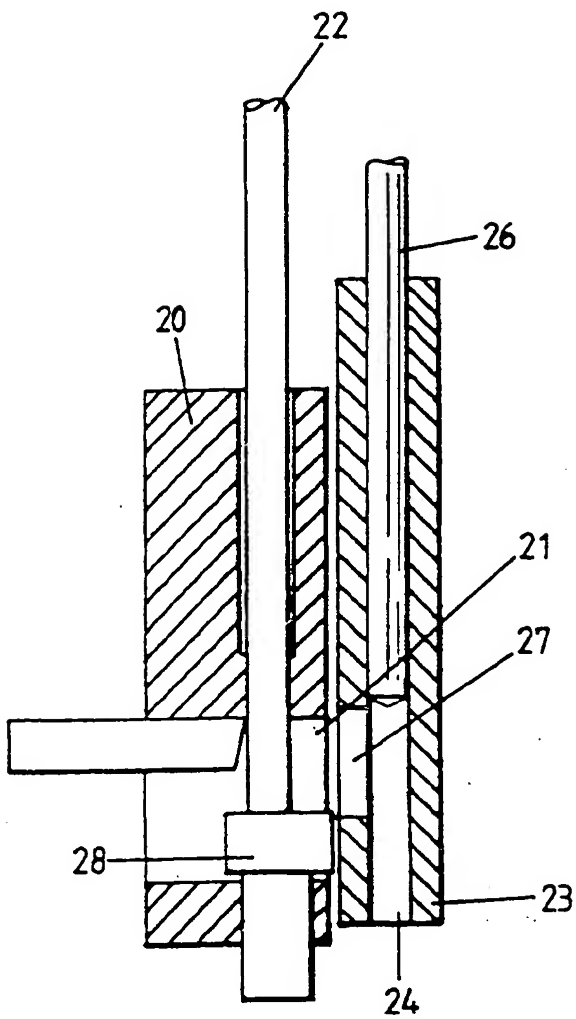


FIG.10

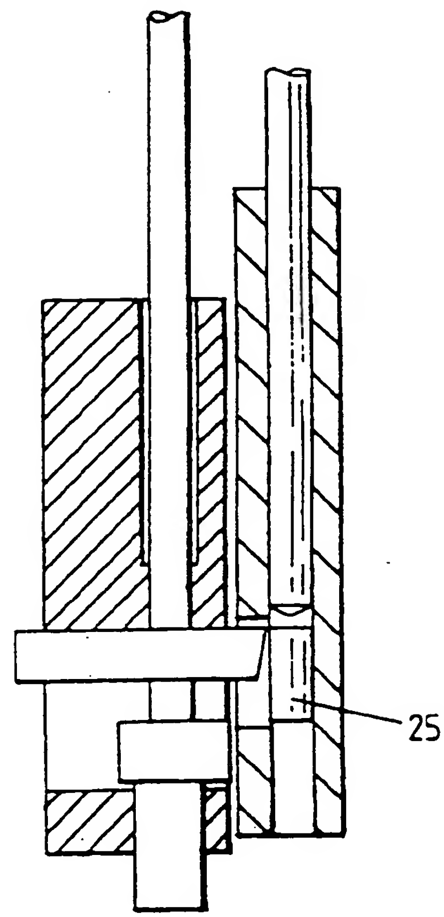


FIG.11

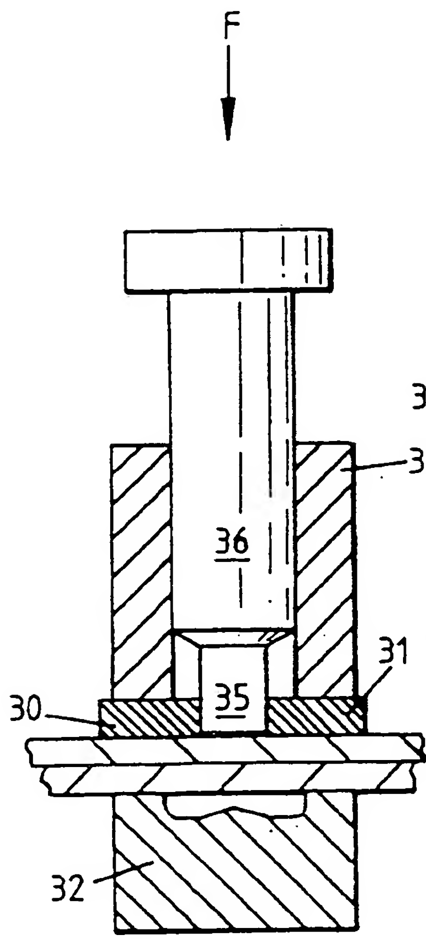


FIG.12

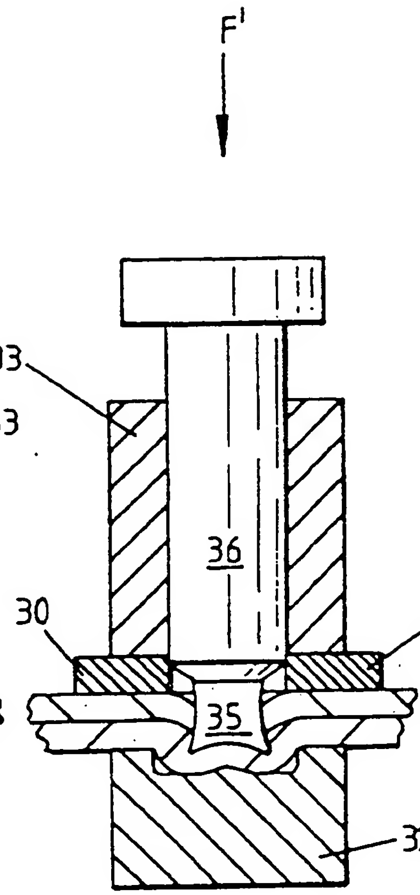


FIG.13

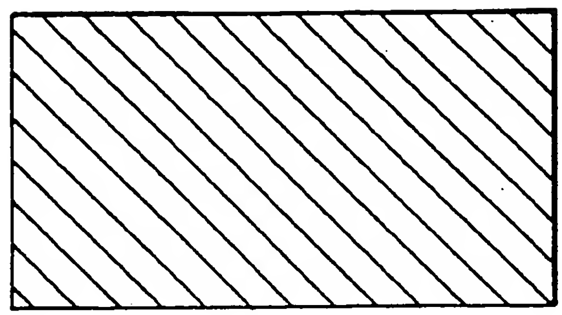

FIG.16

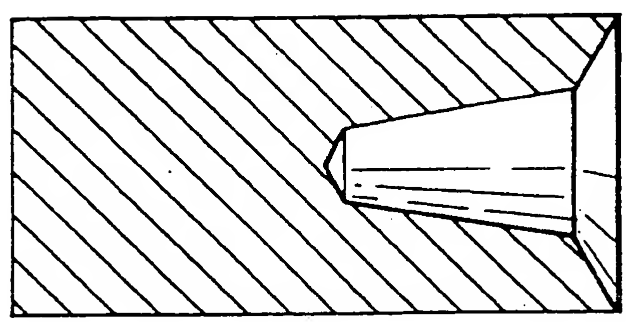

FIG.15

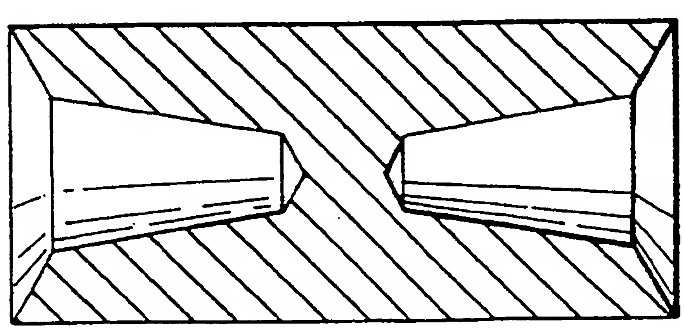

FIG.14

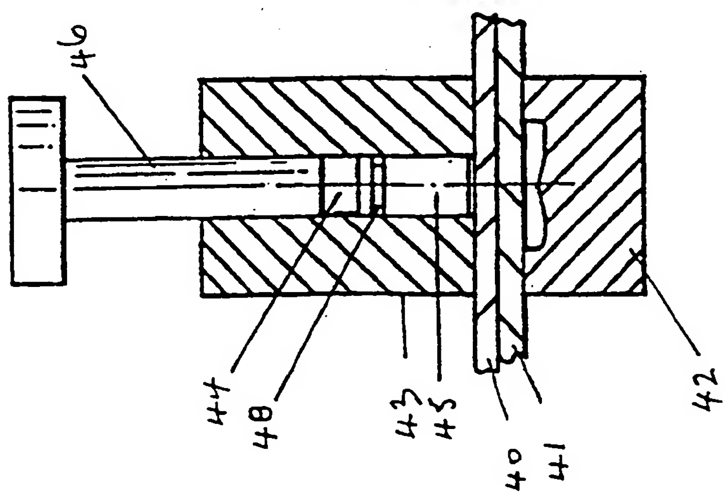


FIG 17

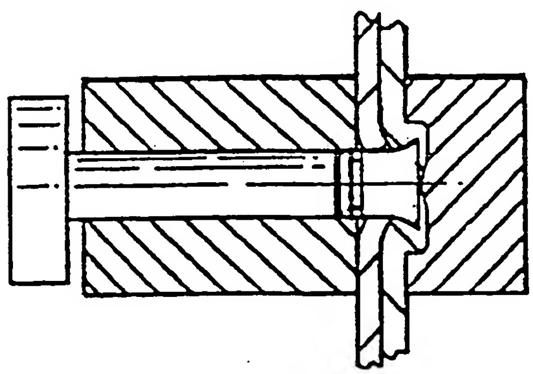

FIG. 18

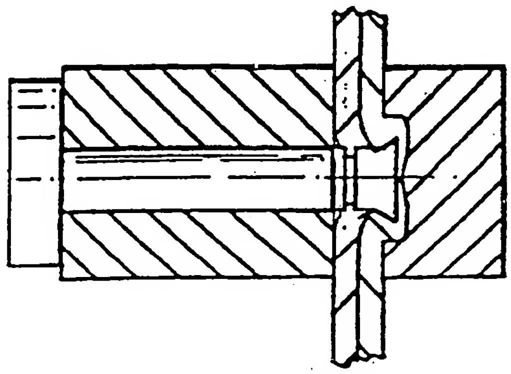

FIG. 19

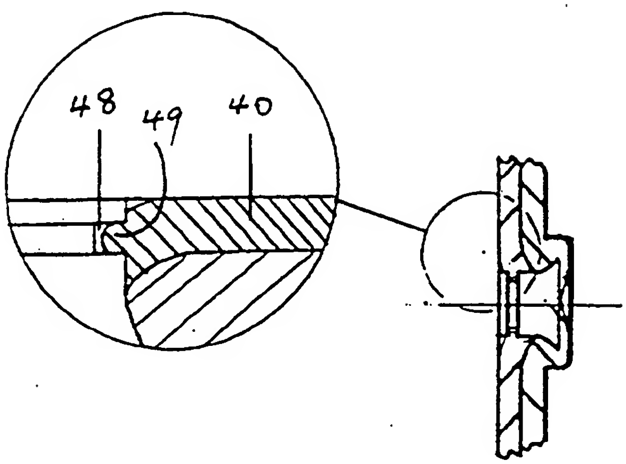


FIG. 20

# INTERNATIONAL SEARCH REPORT

International application No
PCT/GB 97/01774

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 F16B5/04

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F16B B21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | WO 95 35174 A (ARIEL IND PLC ;EDWARDS KENNETH (GB)) 28 December 1995<br>see the whole document | 1 |
| X | WO 93 10925 A (HENROB LTD) 10 June 1993<br>see page 8, line 15 - page 8, line 27; figures 13-16 | 1-5,11,<br>12 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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1

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 16 October 1997 | 07.11.97 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Areso y Salinas, J |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 97/01774

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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| | | EP 0760722 A | 12-03-97 |
| WO 9310925 A | 10-06-93 | AU 670418 B | 18-07-96 |
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